On the cause of alternate bearing in the apple

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(WITH PLATES 1–3 AND A TEXT FIGURE)

I

The production of a heavy crop of fruit every other year, or alternate bearing, is a well-marked phenomenon in the apple and pear, and is not unknown in certain plums and cherries. Alternate bearing in the apple, however, has been more particularly recorded by American horticultural writers, who have proposed a variety of ways of obviating this vexatious propensity.

Thacher* remarks that trees that are allowed to stand unpruned bear only every other or third year, and his remedy for irregular bearing is the knife.

Downing† states that the apple bears in alternate years, but that when the fruit is thinned a tree will bear every year "as it will also if the soil is kept in high condition."

Cole‡ observed that apple trees are inclined to bear in the even numbered years (1846, '48, '50) and lightly in the odd years (1845, '47, '49) and expresses the view that removing the blossoms will change the bearing year.

Fitz§ recognizes alternation of bearing in the apple and states that the most profitable way to obtain annual crops is by proper tillage and proper fertilization.

Thomas‖ believes that thinning the fruit while the applies are small will induce regular bearing and that picking off all the fruit in the fruitful year will change the year of crop abundance.

Maynard¶ states that in most apple orchards large crops of

* Thacher, J. The American Orchardist, Ed. 2, 69. Plymouth, Mass. 1825.

† Downing, A. J. The fruits and fruit trees of America, 61. New York and London. 1845.

‡ Cole, S. W. The American fruit book, 87. Boston. 1850.

§ Fitz, James. The southern apple and peach culturist, 118. Richmond. 1872.

‖ Thomas, J. J. The American fruit culturist, Ed. 20, 243. New York. 1897.

¶ Maynard, S. T. Successful fruit culture, 44. New York. 1905.

fruit are only produced biennially and that in the northern fruit sections the productive year has become more or less fixed on the even year. Alternation of bearing may be brought about by overproductiveness resulting in an exhaustion of the tree which then requires one or more years to develop flower buds again, or it may be due to climatic agencies.

According to Maynard the bearing year may be changed: 1st, by removing part or all the fruit; 2d, by manuring the orchard during the productive year with bonemeal and potash, or bonemeal and wood ashes, or by using nitrate of soda or stable manure in the unproductive year; 3d, by seeding the orchard to grass during the bearing year; 4th, by ploughing the land in the unfruitful year and cultivating during the productive year; 5th, by canker worms or vernal frosts destroying the blossoms.

Powell* observes that the alternate bearing habit once acquired will in all probability be kept up indefinitely. Alternate bearing is brought about by unfavorable climatical conditions, such as hibernal cold or damp weather at blossoming time.

Waugh† notes that alternate bearing is particularly marked in the Baldwin apple and believes that more regular productiveness could be obtained by thinning the fruit.

What is the cause of biennial bearing in the apple and what is the *raison d'être* of the methods proposed to equalize fruitfulness?

II

The biennial bearing of apple trees was credited to its proper cause by Jules Courtois in a lecture before the Horticultural Society of Seine-et-Oise. Hardy‡ quotes at length from the report of this lecture, and from this quotation I translate the following passages bearing on the question of the alternation of bearing in the apple:

> Again one often sees in pear and apple trees flower buds forming like *bouquets de mai*§ of the stone fruits the second year and expanding the third.
>
> There is even a kind of an eye‖, the eyes of the purse (*bourse*), of which this is

* Powell, E. P. The orchard and fruit garden, 14. New York. 1905.

† Waugh, F. A. The American apple orchard. New York. 1912.

‡ Hardy, J.-A. & A.-F. Traité de la taille des arbres fruitiers, Ed. 12, 123. Paris.

§ Floral development on a spur, *lambourde*.

‖ In horticultural literature an "eye" is a bud that will produce a leafy axis, and a "bud," or "fruit-bud," is a bud that will produce a floral axis.

practically the normal mode of development. Developing at the same time as the flowers at the base of the floral axis or purse, these eyes become ordinarily during the same season, buds crowned by three or four leaves, unless an exuberance of sap forces them to grow into leafy shoots. During the second year they develop into buds crowned by six to eight leaves, or floral buds and develop into flower clusters the third. It is due to the fact that the purse eyes require two years to form flowers that we have alternation of floriferousness in the orchard-grown pome fruits when they are in full bearing and consequently growing moderately. The first year of the development of the purse eyes coincides with the bearing year.

The infertile year which follows is the second year of the existence of the purse eyes which develop that year into flower buds. These latter opening the following year give rise to another floriferous year and so on for succeeding years.

A study of the method of flowering of the apple will show that Courtois's explanation was sound and that it satisfactorily explains biennial bearing.

In our fruit trees we may distinguish two classes of branches: 1. Branches of the first order, or structural branches; 2. Branches of the second order, or fruit branches.

A structural branch in its first year of growth is called a leader.

Fruit branches, on the other hand, are of several kinds. In the case of the apple we can distinguish: (1) The fruit branch (*rameau à fruit*); (2) The sprig (*brindille*); (3) The dart (*dard*); (4) The spur* (*lambourde*).

A *fruit branch* is a leader in which the terminal and axillary buds in the upper two thirds or thereabouts of its length become flower buds during the season of its development (PLATES 1, FIG. 2, and 2). The flower buds borne laterally on the leader have been described as formed axillarly by D'Albret† and by Gourley,‡ though they are in reality borne terminally on almost sessile spurs (*lambourdes*). A close study during the first season of the buds from which the supposed axillary clusters arise will show that at the close of vegetation the buds are subtended by a rosette of leaves and are not in the axil of a single leaf. The buds are, therefore, terminal on sessile spurs and not axillary, as by definition an axillary bud is a bud borne in the axil of a leaf. Forney is also of this opinion for he states that "it often happens that the eyes

* The *dard* and *lambourde*, which I have distinguished from one another, are called indiscriminately spurs in the Anglo-Saxon horticultural literature.

† D'Albret. La taille des arbres fruitiers, Ed. 4, 7. Paris. 1842.

‡ Gourley, J. H. Studies in fruit bud formation, New Hampshire Agr. Exp. Sta. Tech. Bull. 9, 17. 1915.

of this season's leader become transformed at once into spurs, and flower perfectly the following year."* In the apple the development of flower buds on fruit branches is not commonly met with (see TABLE I) and is said to occur only in very fertile trees, or trees weakened by transplantation or soil exhaustion.

The *sprig* (*brindille*) is a shoot about a foot or so in length which develops from two-year-old wood, from dormant eyes in older wood, or even from purse eyes. The sprig produces not infrequently a terminal flower-bud the year of its formation, thus behaving in a very similar manner to a leader that has become a fruit branch. In the apple the sprig is not an uncommon form of a fruit branch.†

The *dart* (*dard*) is a short, stout branch possessing smooth bark and growing out from the supporting branch at about a right angle, in its most typical form, that is, when derived from a spine. In its atypical form (PLATE 3, FIG. 1), the only one met with in the apple, it is simply a very short spine-like branch with smooth bark. The dart may also develop from a purse and it is usually considered that the health and vigor of a spur depends on its having been derived from a dart or to the development of a dart or darts at some subsequent time (PLATE 1, FIG. 1). In very fertile varieties of the apple the dart may produce a terminal flower-bud the year of its formation.‡ Usually, however, it only flowers the third year. When the dart forms a flower bud the first season of its growth the floral bud will be found nestling in a rosette of leaves, the apex of the dart having become immediately transformed into a spur (*lambourde*). But if the floral bud is to form at the end of the second season then the apical bud will behave in the manner characteristic of the apical buds of a spur at the close of the first year's vegetation, that is it will be subtended by a rosette of three or four leaves.

The *spur* (*lambourde*) (PLATE 3, FIG. 2), is a short, thick, brittle branch with much wrinkled bark and breaking readily with a smooth fracture. The crests of the wrinkles are nodal points, the troughs internodal points. The axillary buds are very inconspicuous and usually remain dormant though they can be

* Forney, E. Taille des arbres fruitiers, Ed. 2, 1: 258. Paris. 1907.

† Barry, P. The fruit garden, 11. New York. 1851; Forney, *loc. cit.* 1: 254.

‡ Berne, A. Manuel d'arboriculture fruitière, 69. Grenoble. 1898; De Mortillet, M. P. Les meilleurs fruits 3: 376. Montpellier. 1868.

made to develop by appropriate means. The spur usually develops from a bud formed during the previous year, that is from two-year-old wood, and requires two seasons' growth to form a flower bud. At the end of the first year the apical bud will be surrounded by a rosette of three to four leaves, and at the end of the second by a rosette of six to eight leaves, and will have become a floral bud, though spurs may develop on a purse that are fertile the year of their formation behaving in this respect like the spurs of a fruit branch. A spur may live for a number of years becoming with age more or less branched, depending on the degree to which the eyes of the floral axes, or purses develop (PLATE 1, FIG. 1).

Besides the methods of flower-bud formation already described one other method deserves to be described. In orchards where second growth occurs it is not infrequently observed that the terminal buds become flower buds immediately.* It should, however, be noted that this mode of florification is not exceptional in its manner of development. Second growth, except in point of origin, is of the nature of a sprig (*brindille*) and we have seen that on this type of fruit-branch apical flower buds form commonly the first year of its development. We have seen, furthermore, that axillary buds on a leader could develop spurs which bore flowers the following season, that spurs could develop on a purse that were fruitful the following season; that the apical bud of a leader also sometimes developed into a spur which flowered the following season. Now it is to be noted that the flower-buds formed in the several ways above mentioned have this one point in common: they grow on the end of a shoot that develops six to eight sessile nodes in a single period of vegetation. In other words an apical bud subtended by six to eight sessile nodes will be a flower-bud, irrespective of the type of branch upon which it develops. The development of the flower-buds is then clearly correlated with growth. But this growth must be sessile, in other words extremely slow and quick maturing, conditions that can only be supplied by a scant but sufficient water supply coupled with conditions favorable for photosynthetic activity.

* Van Mons, L. B. Arbres fruitiers 1: 108. Louvain, 1835; Gourley, J. H., *loc. cit.*

Of the various ways in which flower buds form in the apple, we may dismiss as of absolutely no importance from the point of view of crop production, flower bud development on second growth, and the same may be said of flower bud development on spurs from leaders of the same age. The following table will show quite clearly that such floral buds produce as a rule but a small part of the total bloom, and this despite the fact that the data were taken by counting random branches round individual trees from the apex of a leader down the branch for a convenient distance.

TABLE I

RELATIVE IMPORTANCE OF SPURS AND FRUIT BRANCHES IN CROP PRODUCTION

Variety	Number of trees examined	Blossom on spurs, per cent.	Clusters on fruit branches, per cent.
Red Astrachan	2	100	0
Early Harvest	2	100	0
Bellflower	1	87.6	12.4
Lyscomb	1	99.42	0.58
Rhode Island Greening	1	100	0
Fallawater	1	90.5	9.5
Duchess	1	98.2	1.2
Wagener	1	89.8	10.2
McIntosh	1	94.6	5.4
Wealthy	2	62.3–95	37.7–5.0
Baldwin	15	100–89.4 (mean 99.09)	0.0–10.6 (mean 0.91)
Peck's Pleasant	2	98.75–97.9	1.25–2.1
Transcendant Crab	1	80.6	19.4

On apple trees of bearing age the leaders may develop apical flower buds during the first year. But this mode of bearing does not play a material part in the total yield of a tree. The crop of apples, at least in years when the yield is good, is produced by the spurs. Let us study, therefore, the behavior of the spurs following their first productive year.

We have seen that a spur usually develops from an axillary bud on two-year-old wood and forms an apical bud subtended by a rosette of three to four leaves, which develops next year into a very short growth bearing a bud subtended by a rosette of six to eight leaves, and experience has shown that such a bud is invariably a flower bud, whereas the apical bud with a rosette of three to four leaves is only potentially floriferous. The flower bud of the apple is a mixed bud, and to this fact we owe certain peculiarities in the growth of spurs to which attention must now be called.

After the flowers have been pollinated and the fruit has set the lower and leafy portion of the floral axis becomes considerably thickened and pursey (PLATE I, FIG. I), hence the name *bourse* given to it by the French and which Dr. Black* has very appropriately anglicized purse. On this purse one or two axillary buds either become spurs, darts or sprigs, or if placed terminally on a leader may and usually do develop a shoot. The spurs form during the current year and either flower the following spring, or, and customarily only do, develop a flower-bud during the second season and bloom in the third, but, should the purse eyes remain dormant the year of their formation then the spurs would not bloom until the fourth year; the darts, which develop readily on purses (see PLATE I, FIG. I) and sprigs flower in the usual way.

Owing to the fact that with few exceptions, spurs only flower on alternate years it must follow that after an apple tree begins to form new growth slowly and bear heavily, a light crop must necessarily follow a heavy crop, for, when the flowering of the spurs synchronizes to such an extent as to give a large yield, the same spurs are not in a position to bear again until the next succeeding year. Alternate bearing in mature apple trees is, therefore, a natural phenomenon and one that could be predicated from the mode of flowering of the tree.

III

Alternate bearing of the apple has been ascribed very generally to exhaustion following the productive year, but this opinion appears to be without foundation, for it is commonly observed that an apple grows well following a productive year which would not possibly be the case were the tree exhausted. Again if the tree were exhausted when it bore heavily it is to be presumed that the spurs would require a longer time to produce flowers than they do when production is light, for a spur weakened from any cause is not a fruitful spur any more than is one that develops with too much vigor. Nor is there any particular justification in Gourley's view† that there is a relation between the amount of starch stored and flower bud development. Flower buds may be

* Black, C. A. The nature of the inflorescence and fruit of *Pyrus Malus*. Mem. New York Bot. Gard. 6: 521. 1916.

† Gourley, J. H. *loc. cit.*

developed on one-year-old wood by defoliation, cutting back,* or cutting into the wood above the eyes as is done when lifting a bud.†

These several methods, dissimilar as they may appear, all cause increase in sap pressure and not an increase in stored starch, behind the buds which thereupon grow into short spurs with apical flower buds. The difference in starch content between fruitful spurs and barren spurs is an effect of the mode of vegetation, not the cause of it. An inspection of fruit spurs will show that those bearing flower buds have more leaves per unit length than those bearing leaf buds and consequently should contain more starch.

But if the theory that alternate bearing is due to exhaustion has little or no foundation, the remedies that have been proposed to overcome the debilitating effect of fruitfulness are not for the most part without value.

According to Beach "systematic thinning of fruit combined with skillful care in other directions, may materially strengthen the tendency of the tree to bear annually"‡ a statement which can not be considered a strong endorsement of the value of thinning for the purpose of equalizing crop production; and effectively a year later we find the same author concluding as a result of experiments on thinning carried out for several successive years that "thinning the fruit did not appear to cause any material change in either the amount or regularity of fruit production,"§ a view that must be considered substantially correct as we shall see.

Thinning the fruit can not be expected to effectively regularize bearing for the reason that this operation can have but the following effects upon the tree:

1st, Thinned trees produce *ceteris paribus* more new growth than non-thinned trees; 2d, The sap drawn into the spurs to maintain the fruit, is diverted after thinning into the eyes of the purse which develop more fully than they otherwise would have done.

The increased growth produced by thinning will, in the normal course of events, flower only in the third year after the thinning was effected, in other words, the growth produced as a result of thinning will become productive a year later than the spurs that were

* Van Tieghem, Ph. Traité de botanique, Ed. 2, 1: 961. Paris. 1892.

† Baron, Philibert. Nouveaux principes de taille des arbres fruitiers. 1858.

‡ Beach, S. A. The thinning of fruit. California fruit grower 27: 4. 1902.

§ Beach, S. A. Thinning apples. New York Agr. Expt. Sta. Bull. 239: 198. 1903.

fruitful during its first year of growth and consequently a certain regulatory effect will be produced, the magnitude of which can be estimated in advance by the number of spurs formed.

As regards the effect of thinning on the fructification of the spurs it should be noted that the purse eyes normally only bloom the third year, though they may, as Goff has pointed out,* bloom the second season, but such behavior is exceptional and there is no evidence at present that thinning advances the time of blooming of the purse eyes.

The value of thinning in regularizing bearing must be small, though there can be little doubt but that it is an adjuvant.

Various cultural operations and methods of fertilization have, as would be expected, quite marked results on the regularity of bearing of apple trees. This is, of course, not surprising. Cultural methods affect markedly the vigor and productivity of plants and it is easy to understand that in any given soil and situation the optimum would be obtained by some one method of treatment rather than another. The data presented in the following table is in this respect instructive.

TABLE II

EFFECT OF CULTURAL METHODS ON PRODUCTIVITY AND REGULARITY OF BEARING OF NORTHERN SPY AND BALDWIN APPLES†

Cultural method employed	Mean yield	1907	1908	1909	1910	1911	1912	1913‡	1914	1915
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Tillage and cover-crop	364	−341	+103	−169	+141	−162	+117	+161	+148	+ 2
Tillage, cover crop and stable manure	381.5	−264.5	−236.5	+111.5	−165.5	+230.5	−193.5	+272.5	+364.5	−118.5
Tillage, cover-crop and chemical manure	420	−291	−298	+219	−302	+153	−259	+407	+180	+191
Sod-mulch	327.2	−298.2	−106.2	−112.2	+ 63.8	− 81.2	+111.8	+199.8	+110.8	+111.8
Sod-mulch and stable manure	470.7	−386.7	−255.7	+ 22.3	+ 55.3	+150.3	− 57.7	+282.3	+242.3	− 51.7
Sod-mulch and chemical manure	417.5	−379.5	−218.5	− 8.5	+142.5	− 47.5	− 1.5	+275.5	+121.5	+116.5

* Goff, E. S. Investigation of flower buds. Wisconsin Agr. Exp. Report 17: 283. 1900.

† After data by Stewart, J. P. Cultural methods in bearing orchards. Pennsylvania Agr. Exp. Sta. Bull. 141: 23. 1916.

‡ In 1913 the Baldwin was seriously and irregularly affected by frost and the yield for the Northern Spy only is given.

The data in the above table show that in the trees under tillage alternate bearing is more pronounced than in the trees under sod-mulch; and that fertilization emphasized alternate bearing whether the trees were in sod-mulch or under cultivation. The trees grown in sod-mulch without fertilization bore more uniformly than under any of the other cultural methods used, which signifies that in the trees so treated there was a more uniform yearly production of spurs than in the others, which in other words means that the yearly growth of the trees must also have been more uniform.

An example will make the above statement clear. Let us assume that we have an apple tree in full bearing and that we have six consecutive years of bearing wood already formed. Let us say that the youngest growth developed in 1916, then the oldest was produced in 1908. Now if the yearly growth has been equal throughout, the number of spurs formed will have been equal and the crops produced identical (TEXT FIG. 1).

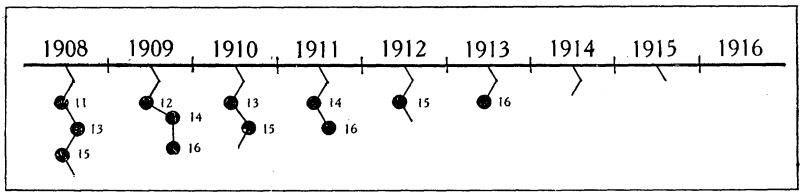

FIG. 1. Diagrammatic drawing showing method of fruiting of the apple.

● = Bearing year; the numbers subjoined in the figure indicate year of fruitfulness.

\ = One year's growth.

> = Two years' growth.

Now let us suppose that the yearly growth was unequal, then the number of spurs formed will have been unequal and productiveness will have exhibited corresponding fluctuations.

There is, therefore, a direct relation between growth and productiveness. In order to produce annual bearing in the apple, and this is a *sine qua non*, one must cause the development of flower-buds to take place in about equal numbers every year. In other words, the bearing surface of an apple tree after it has reached maturity should not be allowed to change, which means that the new growth should be regular and always sufficient to

compensate for the decrease in fertility and death of the spurs on the older bearing wood. Pruning may be considered as the most potent means of regularizing bearing, in fact the only really effective means of accomplishing this object, as Columella* pointed out long ago. By pruning one can maintain the proper balance between vegetative vigor and reproductive vigor. By judicious pruning spurs can be made to develop in proper number so as to fully garnish the two-year-old wood and even to form on the current season's growth.† Again the spurs themselves can be rendered more productive by judicious pruning.‡

In conclusion I would lay down the following axiom: To obtain regular fruitfulness in apple trees of bearing age the yearly departures from the mean growth must be small.

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* Columella, L. J. M. De rei rustica. Venice. 1523.

† Van Tieghem, Ph. *loc. cit.* Baron, *loc. cit.*

‡ Hardy, *loc. cit.* Forney, *loc. cit.*

Description of plates 1-3

PLATE 1

FIG. 1. An old spur showing mode of growth and component parts:—spurs, purses and darts.

FIG. 2. A fruit branch taken from a Transcendant Crab showing lateral inflorescences on sessile spurs.

PLATE 2

A fruit branch taken from a Wealthy apple, showing the lateral inflorescences borne on very feebly developed spurs.

PLATE 3

FIG. 1. A dart in flower.

FIG. 2. A spur in flower.

BUTLER: ALTERNATE BEARING IN THE APPLE

BUTLER: ALTERNATE BEARING IN THE APPLE

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BUTLER: ALTERNATE BEARING IN THE APPLE